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CONTACTS

Phone: **97-748-70-03**

Website: https://ist-journal.uz

Email: munis.iriskulova@gmail.com

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Editorial board:

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APPLICATION OF A LINEAR PROGRAMMING PROBLEM TO ANALYZE THE STATE OF A COMPANY'S COMMODITY AND RAW MATERIAL RESOURCES

Musayeva Shoira Azimovna
OOO "SAM ANTEP GILAM"
Professor of Samarkand Institute of Economics and Servic
Email:musaeva_shoira@mail.ru
ORCID: 0009-0000-9577-6976

Abstract: The tools of economic analysis of enterprise activity are connected with processing of large volume of information, which is dynamic in nature and requires an integrated system of monitoring of the production state. One of the objects of economic analysis is the state and assessment of commodity and raw material resources of the production enterprise. The problem is that, firstly, commodity stocks are in constant motion, and secondly, they freeze working capital, which seriously affects the efficiency of using working capital. This article is devoted to the possibilities of using the linear programming problem in economic analysis to improve the objectivity and reliability of economic assessments.

Key words: production, inventory, linear programming, simplex method.

INTRODUCTION

One of the key factors for achieving high results and increasing the efficiency of an enterprise is the effective management of the formation and use of material resource stocks. The purpose of creating material resource stocks is to smooth out the different intensities of material flows interacting with the production process to ensure the continuity and rhythm of the latter. An important component of commodity and material resource management is the analysis of their structure, volumes and dynamics of change. Analysis of the state of commodity and raw material resources is a comprehensive study of the structure, dynamics, volume, quality and efficiency of use of material stocks of an enterprise or industry. It includes an assessment of the availability of the necessary raw materials for production, identification of factors influencing the formation and expenditure of resources, as well as the search for ways to optimize them.

LITERATURE ANALYSIS

Material resources are the object of research by many scientists. For example, according to A.M. Gadzhinsky (2017) [1]: "Material stocks are products for industrial and technical purposes, consumer goods and other goods at different stages of production and circulation, awaiting entry into the process of industrial or personal consumption." T.B. Berdnikova (2020) [2] believes that "stocks are assets that meet the following criteria: − in the form of raw materials and materials intended for use in the production process or provision of services; − intended for sale in the normal course of business; − are in the production process." According to A.P. Gradov (2012) [3], this is one of the key components of the production potential of an enterprise, including raw materials, materials, semi-finished products and finished products. Other authors, such as V.I. Belov (2015)[4] considers commodity and raw material potential as a factor in business sustainability, which affects production capacity, supply policy and enterprise costs. In the works of Yu.N. Kovalev (2018)[5] the need to analyze not only quantitative but also qualitative characteristics of resources is emphasized, which is important for effective inventory management.

It should be noted that the availability and management of commodity stocks cannot be considered in isolation from the overall commodity potential, since it is the potential that determines the enterprise's ability to ensure uninterrupted production, flexibility in resource management and adaptation to changes in market conditions.

L.M.Ivanova (2020) [6] defines the analysis of the commodity and raw material potential of an enterprise as a comprehensive assessment of the enterprise's resources, including raw material stocks, materials and finished products, in order to determine their sufficiency, efficiency of use and impact on production and economic indicators.

For an industrial enterprise, the objects of this direction of analysis areraw materials and basic materials, auxiliary materials, semi-finished products, finished products in stock, goods in transit, as well as reserve and safety stocks in production.

This analysis helps identify problems with shortages or excess stocks, forecast needs, assess the economic feasibility of purchases, and develop strategies for effective resource management in changing market conditions.

RESEARCH METHODOLOGY

The linear programming (LP) model [7] is a mathematical model used to optimally allocate limited resources to maximize profits or minimize costs. It describes economic processes using a linear objective function and a system of linear constraints that reflect resource availability, demand, production capacity, and other economic factors.

Formally, the linear programming problem is defined as follows:

1.Objective function– expresses the economic indicator that needs to be optimized (maximize income or minimize costs):

$$Z = \sum_{j=1}^{n} c_j x_j \qquad (1)$$

Where x_j – decision variables, and – are economic coefficients (for example, profit per unit of output or cost of resources). c_j

2. Restrictions– a system of linear equations or inequalities that reflect constraints on resources, demand, and production capacity:

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i , i = 1,2,\dots,m \qquad (2)$$

where: – resource consumption coefficients, – available resources. a_{ij} b_i

Non-negativity constraints – variables cannot be negative:

$$x_j \geq 0, \qquad j = 1,2,\dots,n$$

One of the popular algorithms for solving the LP problem is the construction of simplex tables.

ANALYSIS AND RESULTS

The enterprise LLC "SAM ANTEP GILAM" is the leading enterprise in the production of carpets and carpet coverings in the Samarkand region. In the production process, it uses various polymer fibers as raw materials, such as polypropylene, polyester, viscose and acrylic, which generally make up the top layer of the carpet. To make the backing (base) of carpet products, a shaft with a cotton or polyester base wound on it is used, which in turn is intertwined with jute fiber to maintain strength. Latex is used to give stability to the carpet and fix the pile.

Today, the production capacity of the enterprise is 13.5 million square meters per year of carpet products of various sizes, density and design. The wide range of raw materials involved in production requires efficient inventory management, which is not always possible under changing market conditions. As a result, financial risks associated with liquidity and turnover of material stocks increase, especially when raw material prices rise or sales volumes of finished products decline.

Preliminary analysiscommodity and raw materialsstocks consists in assessing the storage duration of various types of raw materials in a warehouse. The sources of data for analyzing the state of the enterprise's commodity and raw material resources are the data from operational monitoring of stocks in the system SAP (Systems, Applications, and Products in Data Processing)companies.

To analyze raw material stocks (acrylic and polyester threads), we studied the structure of warehouse stocks as of 01.02.2025 and 01.03.2025, classifying them into groups by storage periods, that is, dividing them into balances for up to 3 months, from 3 to 6 months, and more than 6 months.

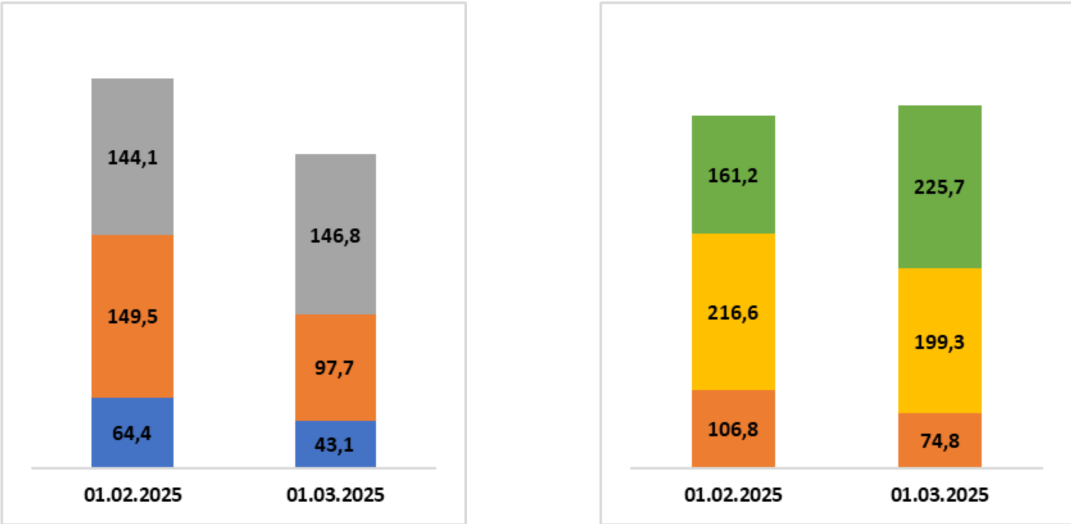

Figure 1. Diagram of changes in the balances of acrylic and polyester threads in the warehouse for the period 01.02.2025 and 01.03.2025 (tn).

Analyzing the balances as of 01.02.2025 and 01.03.2025, we can see that in both types of raw materials there is an excessive accumulation of old batches that are stored for more than 3 months (85% for acrylic and 87% for polyester). The increase in the shelf life of raw materials in the warehouse is primarily due to the interdependence of threads of different colors and density in the manufacture of carpets of a certain collection. Any shortage of one item (color) makes other stocks less liquid and increases the volume of old, unclaimed batches in warehouses. On the other hand, there is a disproportion in volumes between production workshops and the purchasing department, due to which more threads are purchased than are actually needed for the release of products.

For a detailed analysis of commodity stocks using LP, we decided to develop an optimization model of linear programming. The simplex method is an algorithm for solving linear programming problems used in economics for the optimal allocation of limited resources. The goal is to achieve maximum profit or minimum costs, observing specified economic constraints (e.g., availability of raw materials, production capacity, demand, etc.).

The method is based on successive improvement of the solution by transition between the vertices of the admissible set, which guarantees finding the optimal plan. Today, this algorithm exists in many packages of applied programming languages such as “Python” and “R”.

As an example, we will provide an extreme model for calculating the optimal rate of thread use for the company OOO “SAM ANTEP GILAM”.

First condition:

Today, the enterprise OOO “SAM ANTEP GILAM” produces 7823 types of collections (of various sizes and designs) which include acrylic. In the SAP system, we extract the planned raw material costs coming per 1 sq.m. of carpet and, using formula (2), we will compose the constraint conditions of the linear programming problem.

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i, i = 1,2,\ldots,m$$

Where is the average consumption of raw materials (acrylic or polyester thread) per 1 sq.m. of carpet, is the remaining thread in the warehouse, and is the volume of optimal carpet production in sq.m. $a_{ij} b_i x_j$

Second condition:Demand is one of the key factors in LP models, as it determines how much product the enterprise needs to produce and sell. To determine demand in the LP problem, we defined the boundaries of possible solutions for the volume of optimal carpet output in square meters, namely:

$x_j \in [D_a; D_b]$; где $D_{a,b}$ – This is the maximum and minimum expected demand for the period.

Third condition:to develop the objective function of the linear programming problem, we used for the variable c_j carpet production stability indicator for j collection:

In our case, the output stability indicator is an indicator that characterizes the degree of variability of output volumes (in this case, carpets) relative to the average level. It allows us to assess the stability of production and is equal to the inverse of the variation coefficient:

$$SG = \frac{\mu}{\sigma} * 100\%$$

the higher this coefficient, the more stable the production volume is over the course of months.This ratio helps companies analyze the sustainability of production and predict possible risks.

Using the following metric, we developed an objective function to maximize:

$$Z = \sum_{j=1}^{n} c_j\, x_j \rightarrow \max$$

Where x_j – the volume of optimal carpet output in square meters, and – is the output stability indicator. The idea of choosing an output stability indicator means that the linear programming algorithm distributes raw materials, focusing on collections in which the output stability coefficient is higher, and then distributes the remaining raw materials to less popular collections. c_j

In matrix form, our model looks like this:

$$M_{i*j} = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1j-1} & a_{1j} & 1 & 0 & \cdots & 0 & 0 \\ a_{21} & a_{22} & & a_{2j-1} & a_{2j} & 0 & 1 & & 0 & 0 \\ \vdots & & \ddots & \vdots & & \vdots & & \ddots & \vdots & \\ a_{i-1,1} & a_{i-1,2} & \cdots & a_{i-1,j-1} & a_{i-1;j} & 0 & 0 & \cdots & 1 & 0 \\ a_{i1} & a_{i2} & & a_{i,j-1} & a_{ij} & 0 & 0 & & 0 & 1 \end{pmatrix}$$

where is a matrix that determines the amount of resources consumed per square meter of j types of carpets (a total of i types of raw materials in the warehouse used for j types of carpets). M_{i*j}

The constraint conditions for the matrix can be represented as a row vector, where b1, b2,… bi is the remainder of the thread in the warehouse. $M_{i*j} b_i = (\, b_1 \quad b_2 \quad b_3 \quad \dots \quad b_i)^T$

The components of the objective function look like , where c1, c2,…, cj are the coefficients of output stability for any collection. $c_j = (\, c_1 \quad c_2 \quad c_3 \quad \dots \quad c_j)^T$

Having created a matrix form for the LP model, below we developed an algorithm that was launched in the R programming environment, via the lpSolve package;

```
Install_packages (lpSolve)
library(lpSolve)
matrix25March = read_excel(“March 2025.xlsx”, range = “X7:BN13650”, sheet = “Sheet1”, col_names = TRUE)
matrix25March = as.matrix(matrix25March)
matrix25March = 0.001*matrix25March
diag_matrix= diag(13,643)
diag_matrix = -1* diag_matrix
mainmatrix = rbind(matrix25March, diag_matrix)
digits = rep(«<=» , 13 719)
limit25March = read_excel(«March 2025.xlsx», range = «DA1:DA13720», sheet = «Sheet1», col_names = TRUE)
optimal25March = read_excel(«March2025.xlsx», range = «CW7:CW13650», sheet = «Sheet1», col_names = TRUE)
optimal25March = unlist(optimal25March)
limit25March = unlist(limit25March)
optimal_model1 = lp(«max», optimal25March, mainmatrix, digits, limit25March)
```

As part of the linear programming problem, we optimized the production plan taking into account the current balances of acrylic and polyester threads in the warehouse and their liquidity as of March 1, 2025.

Based on the analysis of the available information, the program obtained the results of possible optimization of stocks for individual types of raw materials. The basis is the actual data for each thread code and their volume in days of consumption (0-90, 91-180, more than 180 days), as well as their liquidity (100-81%, 80-61%, 60-41%, 40-21%, less than 20%).

Based on the modeling results, more than 700 positions of acrylic and polyester threads were analyzed. The model distributed raw materials into five groups according to the degree of optimal use, from 100%-80% to 20%-0% (Table 1).

Table 1. Overall results by liquidity groups:

Optimal Use Group	Acrylic thread	Polyester thread
100% – 81%	7%	12.7%
80% – 61%	3%	13.4%
60% – 41%	12%	9.1%
40% – 21%	27%	19.5%
20% – 0% (low liquidity raw materials)	**52%**	**45.2%**

CONCLUSION

Using an extreme model of raw material optimization onSAM ANTEP GILAM LLC demonstrated high efficiency and promising capabilities of linear programming in solving production problems. Based on the results of solving this local problem, the following conclusions can be made:

Only 7% of acrylic and 12.7% of polyester threads can be classified into the first (most efficient) group with a utilization rate of 100%–80%. This indicates a narrow range of threads effectively involved in the production process;

Almost a quarter of the acrylic yarns (27%) and a fifth (19.5%) of the polyester yarns fell into the category with an optimality of 40%–20%, and more than half (52%) of the acrylic yarns and almost half of the polyester yarns (45.2%) fell into the least efficient group (less than 20%), indicating an imbalance between raw material reserves and production needs;

acrylic threads with a long shelf life (over 180 days) account for more than 40% of the total balance, while most of them are not involved in the current production plan - this is a signal for the need to revise the raw material procurement planning policy;

Among polyester threads, the largest volume of thread is concentrated in the 90-180 day storage category, while a significant portion of them are not included in the highly effective groups, which may indicate a slowdown in the production cycle or the irrelevance of these positions for current demand.

Thus, the linear programming model not only proved the need to optimize raw material reserves, but also clearly showed what potential measures of influence need to be taken to maximize production volumes under the current policy of managing commodity and raw material resources.

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